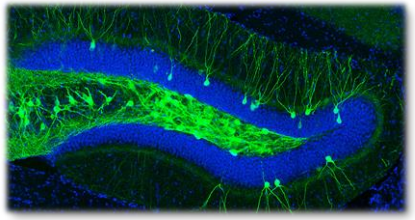
IOS: Integrating Across Scales….

Neural Systems Cluster: *From brains to behavior*



Behavioral Systems Cluster: *How & why animals do what they do*

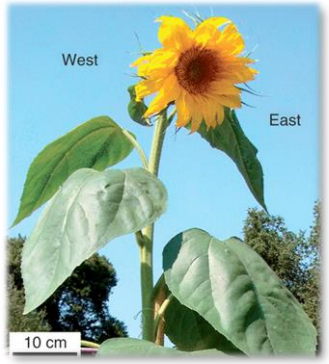
Developmental Systems Cluster: *Building complex life forms*

Plant Genome Research Program Cluster: *Dynamic and responsive genomes*

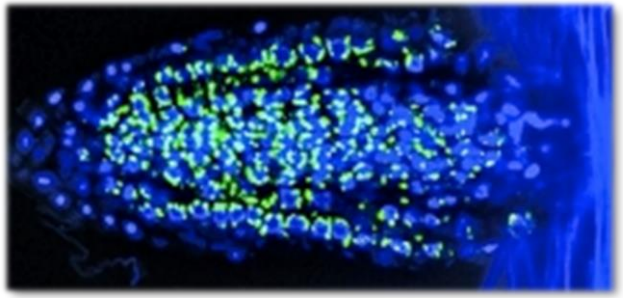
Physiological & Structural Systems Cluster: *Underpinnings of adaptive traits*

…..Discovering Overarching Rules

A Tale of Two Fields



- Genomics and Epigenomics – Conceptually grounded and technically enabled

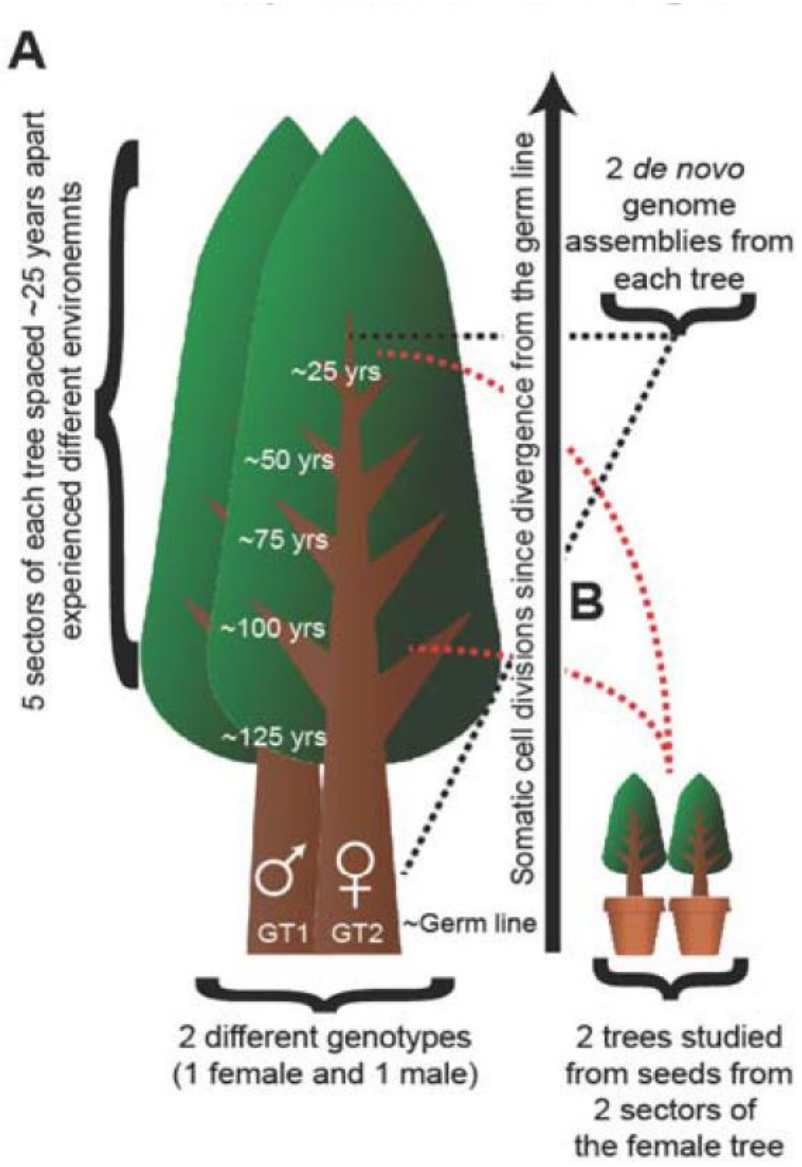


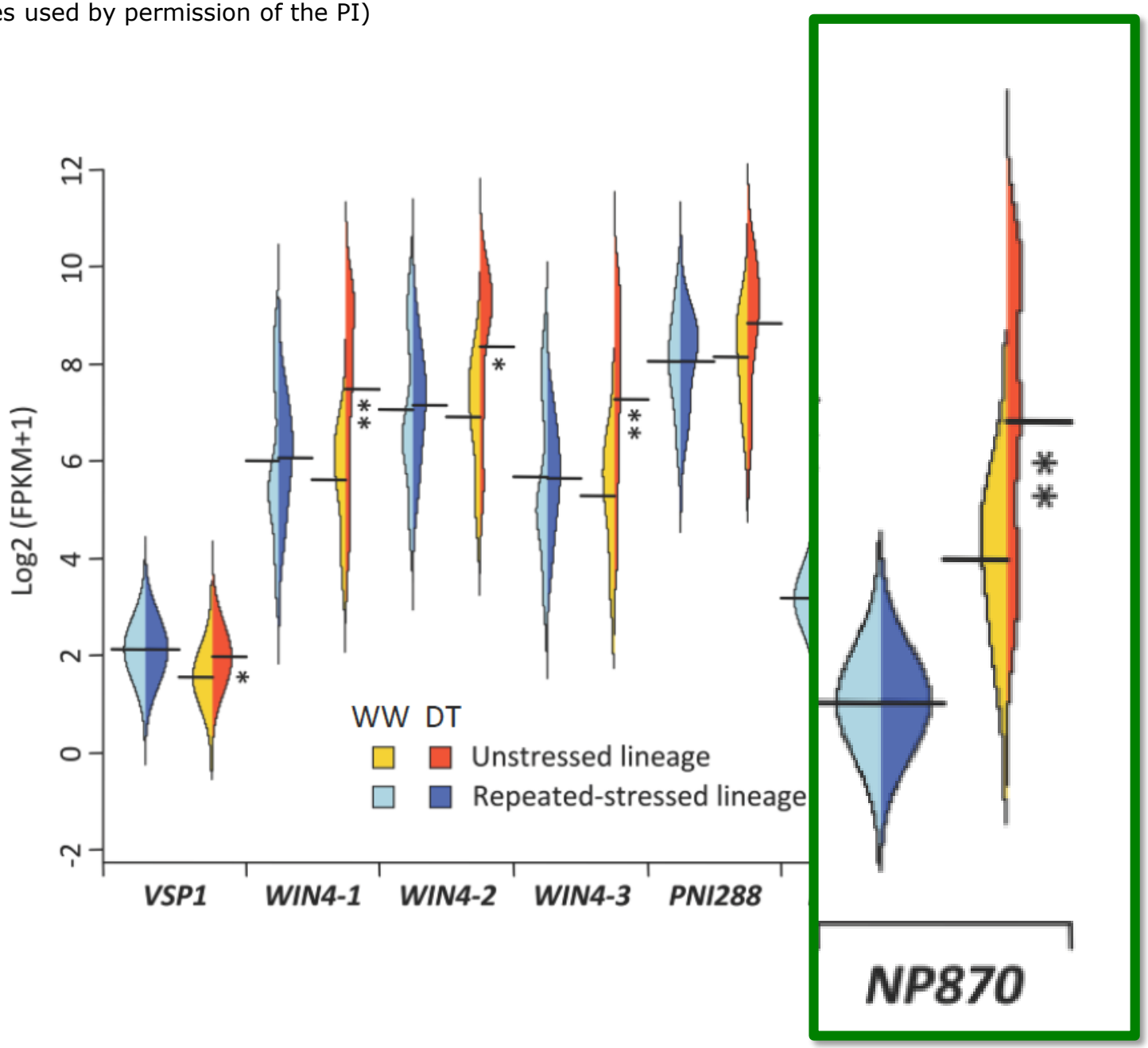
- Microbiomes – Conceptually in flux, uncertain explanatory framework

Michael Mishkind
BIO/IOS/PSS

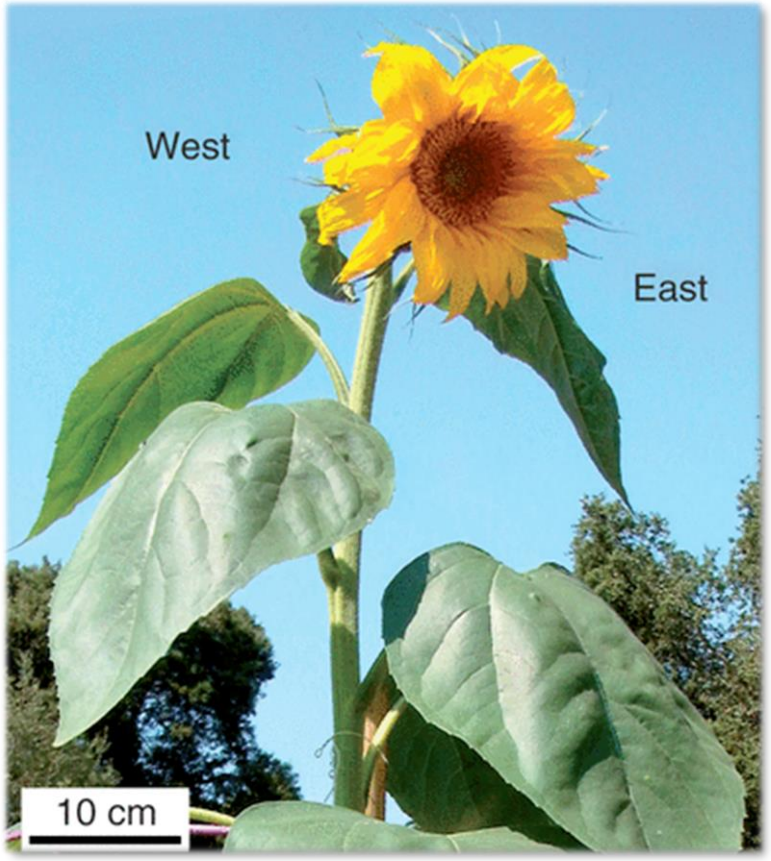
Anne Sylvester
BIO/IOS/PGRP

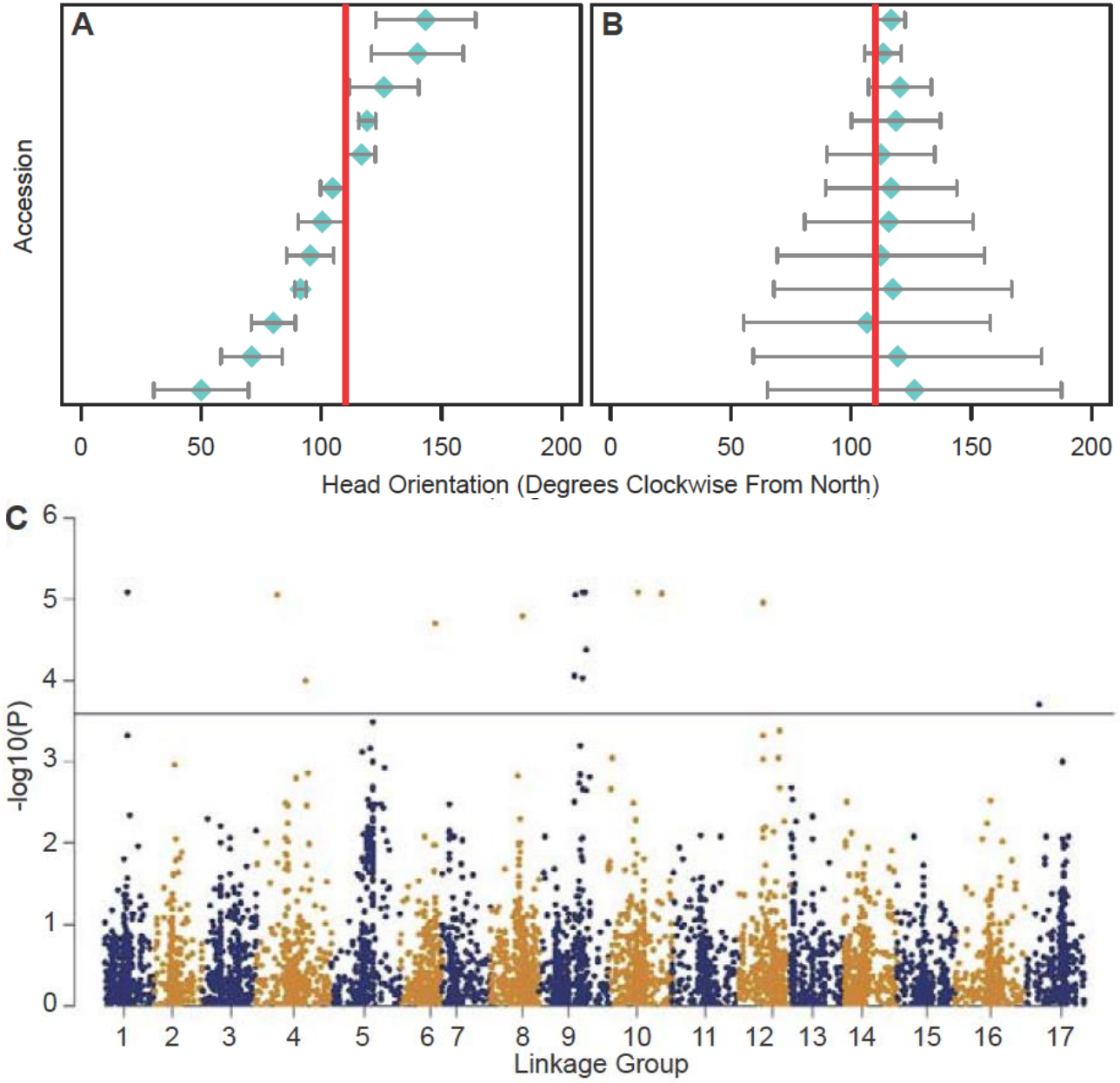
ECA-PGR: Somatic Genetic and Epigenetic Variations in Long-lived Perennial Trees and their Interactions with the Environment. **Robert Schmitz** (IOS-1546867) (figures used by permission of the PI)





Investigating the Mechanistic Basis and Adaptive Significance of the Coordination of Plant Growth by External and Internal Cues. **Stacey Harmer** (IOS-1238040, IOS-1547465)





PLOS | BIOLOGY

Host biology in light of the microbiome: Ten principles of holobionts and hologenomes

Seth R. Bordenstein & Kevin R. Theis (IOS-0920505, DBI-0939454, DEB-1046149, IOS-1456778)
Published 18 August 2015

Box 1. **The Ten Principles of Holobionts and Their Hologenomes**

X. Holobionts and their hologenomes do not change the rules of evolutionary biology

a gene in the nuclear genome to a microbe in the microbiome

VII. The hologenome concept fits squarely into genetics and accommodates multilevel selection theory
VIII. The hologenome is shaped by selection and neutrality
IX. Hologenomic speciation blends genetics and symbiosis
X. Holobionts and their hologenomes do not change the rules of evolutionary biology

PLOS | BIOLOGY

ESSAY

The Hologenome Concept: Helpful or Hollow?

Nancy A. Moran, Daniel B. Sloan (IOS-1415604, MCB-1412260)

Published 4 December 2015

Box 1. **Misconceptions Related to the Hologenome Concept**

Misconception #2: Parallel phylogenies of host and symbiont, or intimacy of host and symbiont associations, reflect coevolution. *Reality: While coevolution can generate parallel phylogenies or intimate associations, these can also result from many other mechanisms.*

Misconception #5: Because of the extreme importance of symbionts in essential functions of their hosts, the integrated holobiont represents the primary unit of selection. *Reality: In most host–symbiont relationships, contrasting modes of genetic transmission will decouple selection pressures.*

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Getting the Hologenome Concept Right: an Eco-Evolutionary Framework for Hosts and Their Microbiomes

Kevin R. Theis,[a,b] Nolwenn M. Dheilly,[c] Jonathan L. Klassen,[d]
Robert M. Brucker,[e] John F. Baines,[f,g] Thomas C. G. Bosch,[h] John F. Cryan,[i,j]
Scott F. Gilbert,[k] Charles J. Goodnight,[l] Elisabeth A. Lloyd,[m] Jan Sapp,[n]
Philippe Vandenkoornhuyse,[o] Ilana Zilber-Rosenberg,[p] Eugene Rosenberg,[q]
Seth R. Bordenstein[r] Published 29 March 2016

"Holobionts and hologenomes are incontrovertible, multipartite entities that result from ecological, evolutionary, and genetic processes at various levels. They are not restricted to one special process but constitute a wider vocabulary and framework for host biology in light of the microbiome."

1st community effort (15 biologists and philosophers) to distill the hologenome concept

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MINIREVIEW

Holes in the Hologenome: Why Host-Microbe Symbioses Are Not Holobionts

Angela E. Douglas,[a,b] John H. Werren[c]

Published 31 March 2016

(DEB-1241099, DEB-125753)

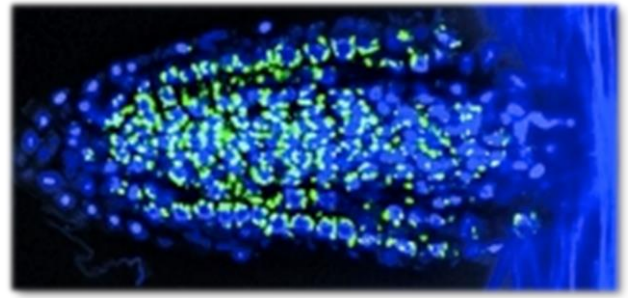
"The intellectual tools provided by the well-established disciplines of ecology, genetics, and evolution provide a rich and effective conceptual framework for analysis of host-microbiome systems."

Salicylic acid modulates colonization of the root microbiome by specific bacterial taxa, Sarah L. Lebeis *et al.*

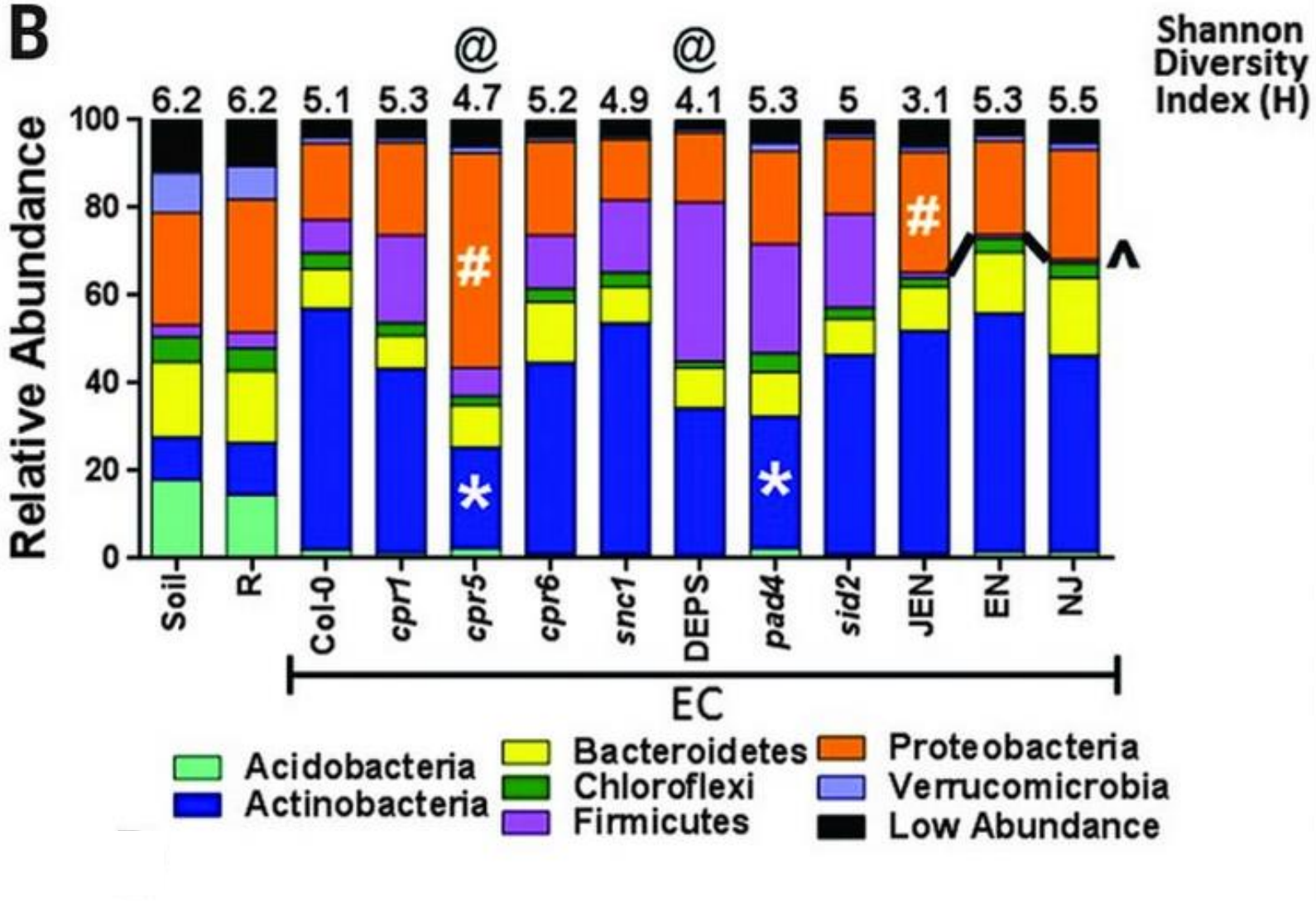
21 August 2015, *SCIENCE* 349:860

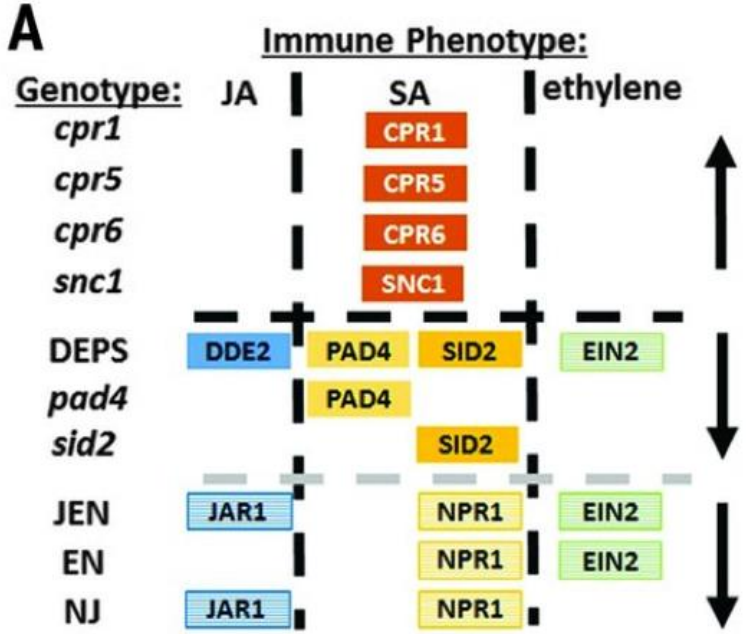
IOS-0958245, IOS-1343020

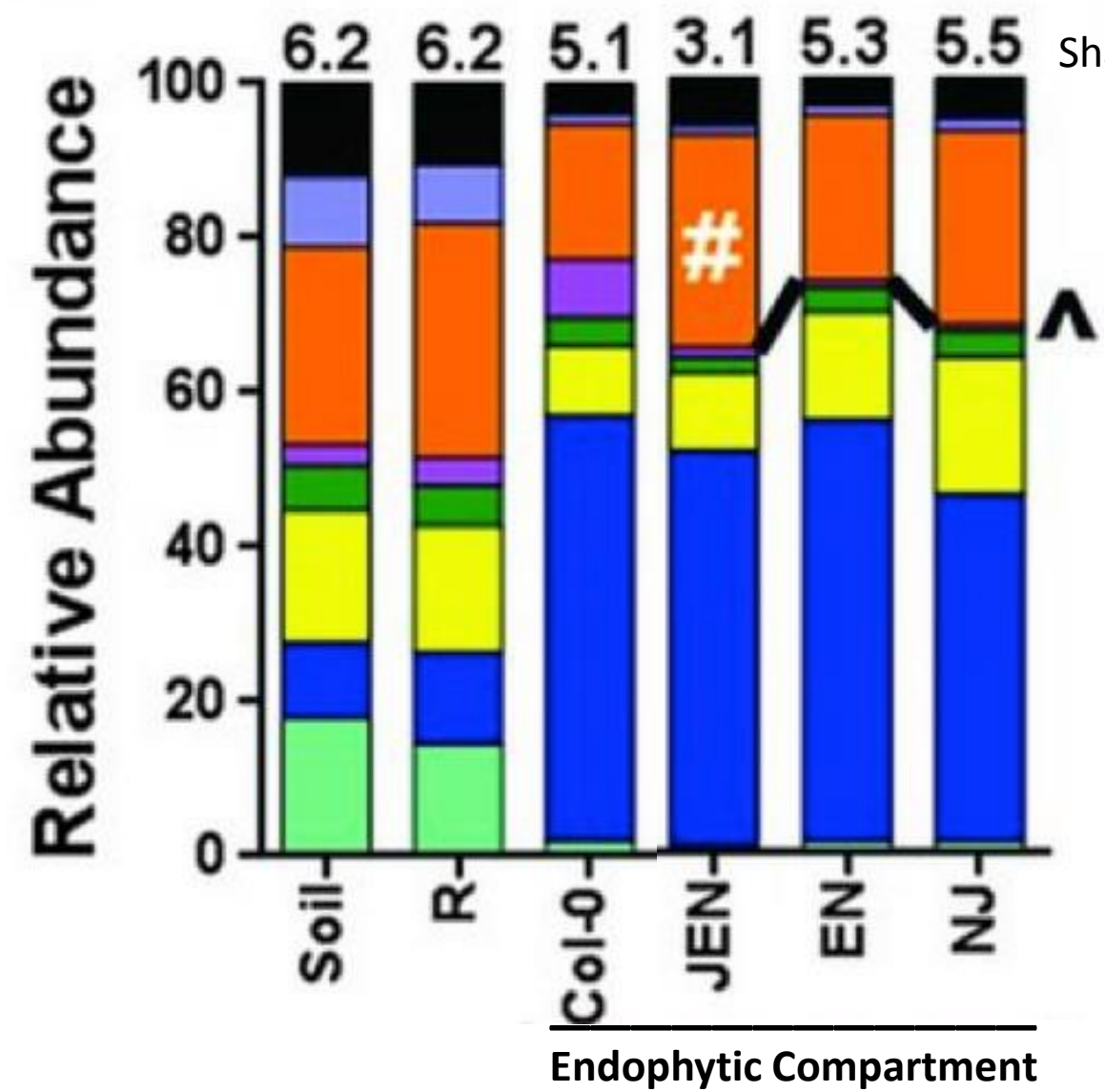
Lateral root with fluorescent bacteria

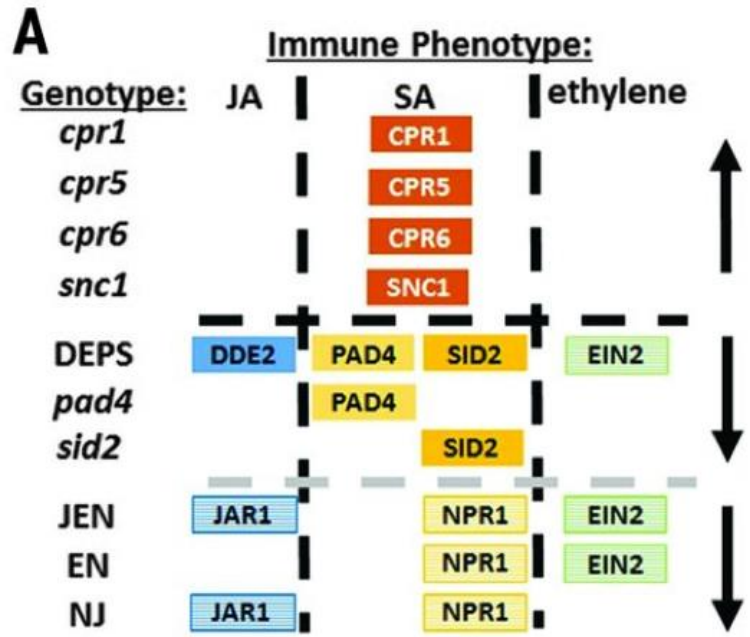


Bacterial communities:






6.2
6.2
5.1
3.1
5.3
5.5
Shannon Diversity Index
Relative Abundance
100
80
60
40
20
0
#
Soil
R
Col-0
JEN
EN
NJ
Endophytic Compartment
Acidobacteria
Actinobacteria
Bacteroidetes
Chloroflexi
Firmicutes
Proteobacteria
Verrucomicrobia
Low Abundance


A
Immune Phenotype:
Genotype:
JA
SA
ethylene
cpr1
cpr5
cpr6
snc1
CPR1
CPR5
CPR6
SNC1
DEPS
pad4
sid2
DDE2
PAD4
SID2
EIN2
JEN
EN
NJ
JAR1
NPR1

How can the study of microbiomes move beyond descriptive and correlative efforts to address biologically significant questions?

Another Box 1. A Functional Perspective on Microbiomes

- What host- and microbe-derived factors influence the assembly and maintenance of microbiomes? What is the function of these factors?
- How do microbiomes and hosts interact metabolically?
- How do hosts select (and reject) microbial partners?
- What roles do microbiomes play during development, physiological adaptation and in attaining and maintaining immuno-competence?
- How are microbial species distributed across hosts at levels of organization ranging from communities to cells? What kinds of micro-heterogeneity in distribution patterns are present and what is its functional significance?
- How do biotic and abiotic stress and climate change influence microbiome structure and function?
- What is the taxonomic diversity of microbes in a microbiome and what is its functional significance? What level of genomic resolution is required for analysis of microbiome function?
- More generally, how can the study of microbiomes move beyond descriptive and correlative efforts to address biologically significant questions?